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NATIONAL DAM SAFETY PROGRAM. CEDAR LAKE DAM (MO 11058), MISSOUR--ETC(U)
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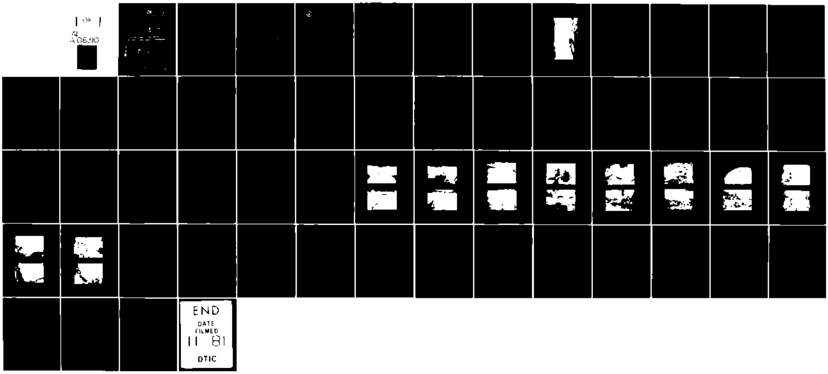

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MISSOURI-KANSAS CITY BASIN

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CEDAR LAKE DAM

BOONE COUNTY, MISSOURI

MO 11058

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PHASE 1 INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM

FILE COPY

United States Army
Corps of Engineers
Serving the Army
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St. Louis District

PREPARED BY: U.S. ARMY ENGINEER DISTRICT, ST. LOUIS

FOR: STATE OF MISSOURI

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report was prepared under the National Program of Inspection of Non-Federal Dams. This report assesses the general condition of the dam with respect to safety, based on available data and on visual inspection, to determine if the dam poses hazards to human life or property.

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MISSOURI-KANSAS CITY BASIN

CEDAR LAKE DAM

BOONE COUNTY, MISSOURI

MO 11058

PHASE 1 INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM

United States Army
Corps of Engineers
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St. Louis District

PREPARED BY: U.S. ARMY ENGINEER DISTRICT. ST. LOUIS

FOR: STATE OF MISSOURI

JULY 1980

DEPARTMENT OF THE ARMY
ST. LOUIS DISTRICT, CORPS OF ENGINEERS
210 TUCKER BOULEVARD, NORTH
ST. LOUIS, MISSOURI 63101

REPLY TO
ATTENTION OF

SUBJECT: Cedar Lake Dam, Mo. ID No. 11058
Phase I Inspection Report

This report presents the results of field inspection and evaluation of the Cedar Lake Dam.

It was prepared under the National Program of Inspection of Non-Federal Dams.

This dam has been classified as unsafe, non-emergency by the St. Louis District as a result of the application of the following criteria:

a. Spillway will not pass 50 percent of the Probable Maximu, Flood without overtopping the dam.

b. Overtopping of the dam could result in failure of the dam.

c. Dam failure significantly increases the hazard to loss of life downstream.

SUBMITTED BY: SIGNED — 29 SEP 1980
Chief, Engineering Division — Date

APPROVED BY : SIGNED — 29 SEP 1980
Colonel, CE, District Engineer — Date

CEDAR LAKE DAM

BOONE COUNTY, MISSOURI

MISSOURI INVENTORY NO. 11058

PHASE I INSPECTION REPORT

NATIONAL DAM SAFETY PROGRAM

PREPARED BY:

BLACK & VEATCH
CONSULTING ENGINEERS
KANSAS CITY, MISSOURI

UNDER DIRECTION OF

ST. LOUIS DISTRICT CORPS OF ENGINEERS

FOR

GOVERNOR OF MISSOURI

JULY 1980

PHASE I REPORT

NATIONAL DAM SAFETY PROGRAM

Name of Dam	Cedar Lake Dam
State Located	Missouri
County Located	Boone County
Stream	Tributary of Little Bonne Femme Creek
Date of Inspection	1 July 1980

Cedar Lake Dam was inspected by a team of engineers from Black & Veatch, Consulting Engineers for the St. Louis District, Corps of Engineers. The purpose of the inspection was to make an assessment of the general condition of the dam with respect to safety, based upon available data and visual inspection, in order to determine if the dam poses hazards to human life or property.

The guidelines used in the assessment were furnished by the Department of the Army, Office of the Chief of Engineers and developed with the help of several Federal and state agencies, professional engineering organizations, and private engineers. Based on these guidelines, this dam is classified as a small size dam with a high downstream hazard potential. According to the St. Louis District, Corps of Engineers, failure would threaten lives and property. The estimated damage zone extends approximately three miles downstream of the dam. Within the estimated damage zone are eleven dwellings, a barn, and four trailers. Contents of the estimated damage zone were verified by the inspection team.

Our inspection and evaluation indicates the spillway does not meet the criteria set forth in the guidelines for a dam having the above size and hazard potential. The spillway will pass neither 50 nor 100 percent of the probable maximum flood without overtopping but will pass 15 percent of the probable maximum flood. The spillway will not pass the flood which has a one percent chance of occurrence in any given year (100-year flood). The spillway design flood recommended by the guidelines is 50 to 100 percent of the probable maximum flood. Considering the downstream hazard zone, the spillway design flood should be 100 percent of the probable maximum flood. The probable maximum flood is defined as the flood discharge which may be expected from the most severe combination of critical meteorologic and hydrologic conditions which are reasonably possible in the region.

Based on visual observations, this dam appears to be in acceptable condition. Deficiencies visually observed by the inspection team were very poor weed cover, many erosion rivulets and gullies on both the upstream and downstream slopes and at the abutment embankment interface,

cracks on crest of dam, large numbers of animal burrows on both the upstream and downstream slopes, and the absence of adequate slope protection on the upstream face. The spillway capacity is reduced by trees growing in the approach channel and sediment in the spillway pipes. Seepage and stability analyses required by the guidelines were not available.

There were no observed deficiencies or conditions existing at the time of the inspection which indicated an immediate safety hazard. Future corrective action and regular maintenance will be required to correct or control the described deficiencies. In addition, detailed seepage and stability analyses of the existing dam, as required by the guidelines, should be performed. A detailed report discussing each of these deficiencies is attached.

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Harry L. Callahan, Partner
Black & Veatch

OVERVIEW OF DAM

PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM
CEDAR LAKE DAM

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SECTION 1 - PROJECT INFORMATION

1.1 GENERAL

a. Authority. The National Dam Inspection Act, Public Law 92-367, authorized the Secretary of the Army, through the Corps of Engineers, to initiate a program of safety inspection of dams throughout the United States. Pursuant to the above, the District Engineer of the St. Louis District, Corps of Engineers, directed that a safety inspection of the Cedar Lake Dam be made.

b. Purpose of Inspection. The purpose of the inspection was to make an assessment of the general condition of the dam with respect to safety, based upon available data and visual inspection, in order to determine if the dam poses hazards to human life or property.

c. Evaluation Criteria. Criteria used to evaluate the dam were furnished by the Department of the Army, Office of the Chief of Engineers, in "Recommended Guidelines for Safety Inspection of Dams." These guidelines were developed with the help of several Federal agencies and many state agencies, professional engineering organizations, and private engineers.

1.2 DESCRIPTION OF PROJECT

a. Description of Dam and Appurtenances.

(1) The dam is an earth structure located in the valley of a tributary to Little Bonne Femme Creek (Plate 1). The watershed is an area of low hills consisting of about 40% residential development, 10% timber and 50% crop and grassland. The large residential lots around the lake contain many trees with well maintained lawns and paved streets which drain to the lake (Plate 2). The dam is approximately 700 feet long along the crest and 33 feet high. The dam crest is 24 feet wide. The downstream face of the dam slopes from the crest to the valley floor below. A service road passes over the crest of the dam. The road is closed to public use by a cable across the crest at the west end of the dam.

(2) The spillway consists of six uncontrolled 42 by 30 inch corrugated steel pipe-arches about 55-feet long set in the dam embankment next to the left abutment. The embankment is 10-feet high at the spillway. The six pipe-arches discharge into a trapezoidal channel cut in soil and rock with a 28-feet bottom width. Most of the channel invert is bedrock and continues to a rock overfall before reaching the natural stream channel. The spillway inlet structure consists of a sloping concrete headwall capping the six pipe-arches and conforming to the embankment slope. The headwall height measures 6-feet on the slope. There is no emergency spillway for this dam.

(3) Pertinent physical data are given in paragraph 1.3.

b. Location. The dam is located in south central Boone County, Missouri, as indicated on Plate 1. The lake formed by the dam is in an area shown on the United States Geological Survey 7.5 minute series quadrangle map for Columbia, Missouri in Section 35 of T48N, R13W.

c. Size Classification. Criteria for determining the size classification of dams and impoundments are presented in the guidelines referenced in paragraph 1.1c above. Based on these criteria, the dam and impoundment are in the small size category.

d. Hazard Classification. The hazard classification assigned by the Corps of Engineers for this dam is as follows: The Cedar Lake Dam has a high hazard potential, meaning that the dam is located where failure may cause loss of life, and serious damage to homes, agricultural, industrial and commercial facilities, and to important public utilities, main highways, or railroads. For the Cedar Lake Dam the estimated flood damage zone extends approximately three miles downstream of the dam. Within the estimated damage zone are eleven dwellings, a barn, and four trailers. Contents of the estimated damage zone were verified by the inspection team.

e. Ownership. The dam is owned by Cedar Lake Association and Cedar Lake Corporation c/o Mr. Francis (Fritz) Daugherty, 3400 Lindrail, Columbia, Missouri, Telephone 314-449-8050.

f. Purpose of Dam. The dam forms a 16-acre lake used for recreation.

g. Design and Construction History. Data relating to the design, and construction were not available. The dam was designed by Marion Clark of Columbia, Missouri.

h. Normal Operating Procedure. Normal rainfall, runoff, transpiration, evaporation, and overflow through the uncontrolled outlet pipes all combine to maintain a relatively stable water surface elevation.

1.3 PERTINENT DATA

a. Drainage Area - 541 acres

b. Discharge at Damsite.

(1) Normal discharge at the damsite is through six uncontrolled 42 by 30 inch pipe-arches which discharge to a trapezoidal earth and rock channel, then continues to a rock overfall before reaching the natural stream channel.

(2) Estimated experienced maximum flood at damsite - Unknown.

(3) Estimated ungated spillway capacity at maximum pool elevation 390 cfs (Probable Maximum Flood Pool El. 686.4).

c. Elevation (Feet above m.s.l.).

(1) Top of dam - 683.9 (see Plate 3)

(2) Spillway pipe invert - 678.6

(3) Streambed at toe of dam - 652.2

(4) Maximum tailwater - Unknown.

d. Reservoir.

(1) Length of maximum pool - 2,800 feet ± (Probable maximum flood pool level)

(2) Length of normal pool - 2,200 feet ± (Spillway pipe invert)

e. Storage (Acre-feet).

(1) Top of dam - 241

(2) Spillway pipe invert - 141

(3) Design surcharge - Not available.

f. Reservoir Surface (Acres).

(1) Top of dam - 23

(2) Spillway pipe invert - 16

g. Dam.

(1) Type - Earth embankment

(2) Length - 700 feet

(3) Height - 33 feet ±

(4) Top width - 24 feet

(5) Side slopes - upstream face 1.0 V on 2.9 H, downstream face between 1.0 V on 3.6 H and 1.0 V on 4.3 H (see Plate 4)

(6) Zoning - Unknown.

(7) Impervious core - Unknown.

(8) Cutoff - Unknown.

(9) Grout curtain - Unknown.

h. Diversion and Regulating Tunnel - None.

i. Spillway.

(1) Type - six 42 by 30 inch corrugated steel pipe-arches.

(2) Inlet invert elevation - 678.6 feet m.s.l.

(3) Outlet invert elevation 678.1 feet m.s.l.

(4) Gates - None.

(5) Upstream channel - Not applicable.

(6) Downstream channel - Excavated trapezoidal channel overfalls to natural stream below the dam.

j. Emergency Spillway - None

k. Regulating Outlets - None.

SECTION 2 - ENGINEERING DATA

2.1 DESIGN

Design data were not available. According to the owner the dam was designed by Marion Clark of Columbia, Missouri.

2.2 CONSTRUCTION

Construction records were unavailable. The dam was constructed by Richardson and Bass Construction Company, Columbia, Missouri.

2.3 OPERATION

Operational records and documentation of past floods were not available.

2.4 GEOLOGY

The site of the dam and reservoir is located in a narrow steep-sided valley. The dam impounds an intermittent tributary of Little Bonne Femme Creek.

The soils of the area consist of the Pershing, Weldon and Union soil series. The Pershing and Weldon are located on ridges and hill-sides and formed in loess. The Union soil series occurs on upland slopes that border the valleys of creeks and are formed in residuum from limestone.

The bedrock in the area of the dam and reservoir consists of lime-stone of the Keokuk and Burlington formations of the Osage Series of the Mississipian System.

2.5 EVALUATION

a. Availability. No engineering data were available.

b. Adequacy. No engineering data were available. Thus, an assessment of the design, construction, and operation could not be made. Seepage and stability analyses comparable to the requirements of the "Recommended Guidelines for Safety Inspection of Dams" were not available, which is considered a deficiency. These seepage and stability analyses should be performed for appropriate loading conditions (including earthquake loads) and made a matter of record.

c. Validity. The validity of the design, construction, and operation could not be determined due to the lack of engineering data.

SECTION 3 - VISUAL INSPECTION

3.1 FINDINGS

a. General. A visual inspection of Cedar Lake Dam was made on 1 July 1980. The inspection team included professional engineers with experience in dam design and construction, hydrology, hydraulic engineering, and geotechnical engineering. The inspection team consisted of Edwin Burton, team leader; Robert Pinker, geologist; Gary Van Riessen, geotechnical engineer; and Andrew Dywan, civil engineer. The dam is in generally good condition. Specific observations are discussed below. No observations were made of the condition of the upstream face of the dam below the pool elevation at the time of the inspection.

b. Dam. The inspection team observed the following conditions at the dam. Some cracks were observed along the crest about 1/2-inch wide and 6-inches deep. The embankment, consisting of silty clay material, was extremely dry. The cracking may be due to the recent very hot dry weather. It should be noted the temperature was 106°F on the day of the inspection. Irregularities were observed in the upstream slope due to erosion caused by wave action and embankment runoff. No instruments to measure the performance of the dam were located.

There was no evidence of seepage in the embankment, foundation or abutments except for a muddy area in the abutment downstream of the dam where the spillway overfall intersects the natural channel. The downstream toe area was noted to be extremely dry. No toe drains or relief wells were observed.

The dam crest, upstream and downstream slopes were observed to have an ineffective weed cover. There was no evidence of any grass having been planted for slope protection. In addition the crest has vehicle tracks, with some rutting, worn across it, and a foot path has been worn along the waters edge on the upstream slope. Presently, there is a cable across the right end of the dam to control traffic.

Many erosion rivulets and gullies were observed on both the upstream and downstream slopes and at the abutment/embankment interface due to runoff prior to the weed cover being established. Most of the erosion gullies on the downstream slope have occurred along the lower 1/4 of the embankment and were 1 to 3-feet wide and 1 to 2-feet deep. The upstream slope has large, poorly graded riprap along about 75-feet of the left end of the dam. No other riprap was observed on the dam. No evidence was found to indicate that the embankment had ever been overtopped.

No evidence was found that a maintenance program was in effect. Many trees of 1 to 1-1/2-inch diameter were growing in the spillway approach channel. Four of the six spillway corrugated metal pipe-arches

were partially filled at the inlet ends. A large number of animal burrows; probably caused by moles, rabbits and mice, were observed on both the upstream and downstream slopes.

c. Appurtenant Structures. The inspection team observed the following items pertaining to appurtenant structures. The spillway consists of six uncontrolled 42 by 30-inch corrugated metal pipe-arches set in the embankment next to the left abutment which discharge into a downstream trapezoidal channel.

There was no evidence of erosion in the spillway except for some pockets developing in the backfill at the sloping concrete inlet headwall. Erosion was also observed at the spillway channel overfall. As noted previously the spillway entrance channel contains sediment which partially fills four of the six CMP's at the inlet ends.

The interiors of the pipe-arches were inspected from the ends and found to be in satisfactory alignment. No evidence of leakage was noted into, out of or around the spillway pipes. Two of the pipes were entirely clear of sediment. One pipe was noted to be compressed at the downstream end to 27-inches high from the 30-inch initial fabrication height. The remaining three pipes were partially full of sediment.

In general, the spillway is considered to be in good condition except for the trees and silting which obstruct flow in the approach channel. It should be noted that an abnormally large spillway discharge would probably not damage the embankment.

There is no emergency spillway for this dam. There is a wastewater treatment plant consisting of an aeration basin, settling basin and pump house, and a small vacation home located just downstream of the dam which could suffer damage from abnormally large flow through the spillway.

d. Geology. The soil in the area of the dam and reservoir consists of silty clay with numerous cobbles of chert and fragments of limestone. The soil is thin to a few feet thick and is formed in residuum from limestone. The soils are located on the upland slopes around the reservoir and above the abutments. Numerous fragments of chert and limestone are present on the crest and downstream surface of the embankment.

Outcrops of limestone were observed along the valley slopes above and below the embankment. The limestone formed the base and part of the sides of the spillway. Silty clay soil with numerous rock fragments overlies the limestone. The limestone is horizontal, medium-bedded with chert layers. Bedding planes are open with widely spaced vertical joints oriented parallel and normal to the embankment.

Samples of the embankment were taken near the center of the downstream crest of the dam using an Oakfield sampler. The material in the samples consisted of silty clay classified as (CL). Based on these samples and visual observations, it is anticipated the embankment consists of silty clay material classified as (CL).

Based on visual observations, it is anticipated the abutments and foundation of the dam consist of limestone overlain by a thin layer of residual or alluvial silty clay soil containing numerous rock fragments. The spillway is cut into limestone bedrock and adjoins the left abutment of the embankment.

e. Reservoir Area. No slumping or slides of the reservoir banks were observed. The watershed immediately upstream of the lake contains large, well maintained residential lots with many trees and large grassy areas. There was no noticeable siltation in the lake.

f. Downstream Channel. The channel immediately downstream of the outlet of the pipe-arch spillway has a limestone rock floor, rocky banks on either side, and heavy with trees both sides of the channel. The limestone rock floor ends at an overfall. The channel downstream of the overfall is a natural channel with heavy tree and brush growth either side. There is an abrupt turn in the channel beyond the overfall. A large outflow from the spillway could possibly top the berm at the abrupt turn and flood the sewage treatment plant below the dam.

3.2 EVALUATION

The various deficiencies observed at the time of the inspection are not believed to represent an immediate safety hazard. They do, however, warrant monitoring and control. The weed cover presently growing on the embankment slopes has been ineffective in preventing erosion of the embankment soil. The erosion rivulets and gullies on the upstream and downstream slopes and at the embankment/ abutment interface should be backfilled with suitable compacted material, and grass or other slope protection should be provided. The absence of riprap on much of the upstream slope of the dam has resulted in wave-action erosion. If not corrected, wave action will continue to erode the embankment and could lead to slope stability problems.

The cracks on the crest can create a problem by providing a starting point for erosion due to surface runoff. The potential for sloughing and sliding of slope segments will increase as additional water enters the cracks. The trees and brush in the spillway approach channel obstruct flow and promote siltation of the spillway pipes which further reduces spillway capacities. The approach channel should be cleared of trees and brush. Burrowing animals will continue to damage the embankment if a control program is not implemented to eliminate them. Piping due to animal burrows can cause embankments to fail.

SECTION 4 - OPERATIONAL PROCEDURES

4.1 PROCEDURES

The pool is primarily controlled by rainfall, runoff, evaporation, transpiration, and capacity of the uncontrolled spillway outlet pipe.

4.2 MAINTENANCE OF DAM

No maintenance was evident.

4.3 MAINTENANCE OF OPERATING FACILITIES

No operating facilities exist.

4.4 DESCRIPTION OF ANY WARNING SYSTEM IN EFFECT

There is no existing warning system or preplanned scheme for alerting downstream residents for this dam.

4.5 EVALUATION

A maintenance program should be initiated which would include the establishment of a good cover of grass on the embankment in order to control erosion of the embankment slopes. The brush and trees in the spillway approach channel should be removed. Measures to correct the erosion on the embankment should include placing riprap on the upstream slope and filling in the rivulets and gullies with suitable material and establishing grass or other slope protection. The cracks on the crest should be repaired. A program should be undertaken to eliminate the burrowing animals.

SECTION 5 - HYDRAULIC/HYDROLOGIC

5.1 EVALUATION OF FEATURES

a. Design Data. No design data were available.

b. Experience Data. The drainage area and lake surface area are developed from USGS Columbia Quadrangle Map. The dam layout is from a survey made during the inspection. Elevations are approximated from ties to USGS map features.

c. Visual Observations.

(1) The spillway appears to be in good condition. The lake level at the time of the inspection was below the inlet level and there was no flow through the pipe-arches. Only the inlet and outlet ends were observable. The spillway pipes discharge into a channel that has a free outfall into a natural channel. There were no obstructions to flow in the channel downstream of the spillway pipe-arches.

(2) Spillway discharges do not endanger the integrity of the dam.

d. Overtopping Potential. The spillway will not pass the probable maximum flood without overtopping the dam. The probable maximum flood is defined as the flood discharge that may be expected from the most severe combination of critical meteorologic and hydrologic conditions that are reasonably possible in the region. The spillway will pass 15 percent of the probable maximum flood without overtopping the dam. The spillway will not pass the 1 percent probability flood estimated to have a peak outflow of 607 cfs developed by a 48-hour, one percent probability rainfall. According to the recommended guidelines from the Department of the Army, Office of the Chief of Engineers, a high hazard dam of small size should pass 50 to 100 percent of the probable maximum flood. Considering the downstream hazard zone, the appropriate spillway design flood should be 100 percent of the probable maximum flood. The portion of the estimated peak discharge of 50 percent of the probable maximum flood overtopping the dam would be 1,950 cfs of the total discharge from the reservoir of 2,320 cfs. The estimated duration of overtopping is 6.0 hours with a maximum depth over the dam of 1.8 feet. The portion of the estimated peak discharge of the probable maximum flood overtopping the dam would be 4,260 cfs of the total discharge from the reservoir of 4,650 cfs. The estimated duration of overtopping is 9.3 hours with a maximum depth over the dam of 2.5 feet. The embankment safety would most likely be jeopardized should overtopping occur for these periods of time.

According to the St. Louis District, Corps of Engineers, the effect from rupture of the dam could extend approximately three miles downstream of the dam. Eleven dwellings, four trailers and, a barn could be

severely damaged and lives could be lost should failure of the dam occur. Contents of the estimated damage zone were verified by the inspection team. There does not appear to be any flood plain regulations or other constraints in force to limit future downstream development.

SECTION 6 - STRUCTURAL STABILITY

6.1 EVALUATION OF STRUCTURAL STABILITY

a. Visual Observations. Visual observations of conditions which affect the structural stability of this dam are discussed in Section 3, paragraph 3.1b.

b. Design and Construction Data. No design data relating to the structural stability of the dam were found. Seepage and stability analyses comparable to the requirements of the "Recommended Guidelines for Safety Inspection of Dams" were not available, which is considered a deficiency.

c. Operating Records. No operational records exist.

d. Postconstruction Changes. No changes have been made since completion of the dam.

e. Seismic Stability. The dam is located in Seismic Zone 1 which is a zone of minor seismic risk. A properly designed and constructed earth dam using sound engineering principles and conservatism should pose no serious stability problems during earthquakes in this zone. The seismic stability of an earth dam is dependent upon a number of factors: embankment and foundation material classifications and shear strengths; abutment materials, conditions, and strengths; embankment zoning; and embankment geometry. Adequate descriptions of embankment design parameters, foundation and abutment conditions, or static stability analyses to assess the seismic stability of this embankment were not available and therefore no inferences will be made regarding the seismic stability. An assessment of the seismic stability should be included as part of the stability analysis required by the guidelines.

SECTION 7 - ASSESSMENT/REMEDIAL MEASURES

7.1 DAM ASSESSMENT

a. Safety. Several conditions observed during the visual inspection by the inspection team should be monitored and/or controlled. These are: erosion along the downstream and upstream slopes and at the abutment/embankment interface, poor protective weed cover, cracking along the crest, the growth of trees and silting in the spillway approach channel and animal burrows in the embankment. Seepage and stability analyses comparable to the requirements of the "Recommended Guidelines for Safety Inspection of Dams" were not available, which is considered a deficiency.

b. Adequacy of Information. Due to the absence of engineering design data, the conclusions in this report were based only on performance history and visual conditions. The inspection team considers that these data are sufficient to support the conclusions herein. Seepage and stability analyses comparable to the requirements of the "Recommended Guidelines for Safety Inspection of Dams" were not available, which is considered a deficiency.

c. Urgency. It is the opinion of the inspection team that a program should be developed as soon as possible to implement remedial measures recommended in paragraph 7.2b. If the safety deficiencies listed in paragraph 7.1a are not corrected, they will continue to deteriorate and lead to a serious potential of failure. The item recommended in paragraph 7.2a should be pursued on a high priority basis.

d. Necessity for Phase II. The Phase I investigation does not raise any serious questions relating to the safety of the dam nor does it identify any serious dangers which would require a Phase II investigation. However, the additional analyses noted in paragraph 2.5b are necessary for compliance with the guidelines.

e. Seismic Stability. This dam is located in Seismic Zone 1. Adequate description of embankment design parameters, foundation and abutment conditions, or static stability analyses to assess the seismic stability of this embankment were not available and therefore no inferences will be made regarding the seismic stability. An assessment of the seismic stability should be included as part of the recommended stability analysis.

7.2 REMEDIAL MEASURES

a. Alternatives. The spillway size and/or height of the dam would need to be increased or the lake level would need to be lowered to increase available flood storage in order to pass the spillway design flood.

b. Operation and Maintenance Procedures. The following operation and maintenance procedures should be carried out under the direction of a professional engineer experienced in the design, construction, and maintenance of earth dams:

(1) Riprap and riprap bedding material should be placed on the upstream face of the dam at the normal lake level to prevent erosion of the embankment material.

(2) The cracking along the crest of the dam should be repaired. The embankment slope should be monitored during this repair.

(3) The erosion rivulets and gullies on the upstream and downstream slopes and at the embankment/abutment interface should be backfilled with suitable compacted material.

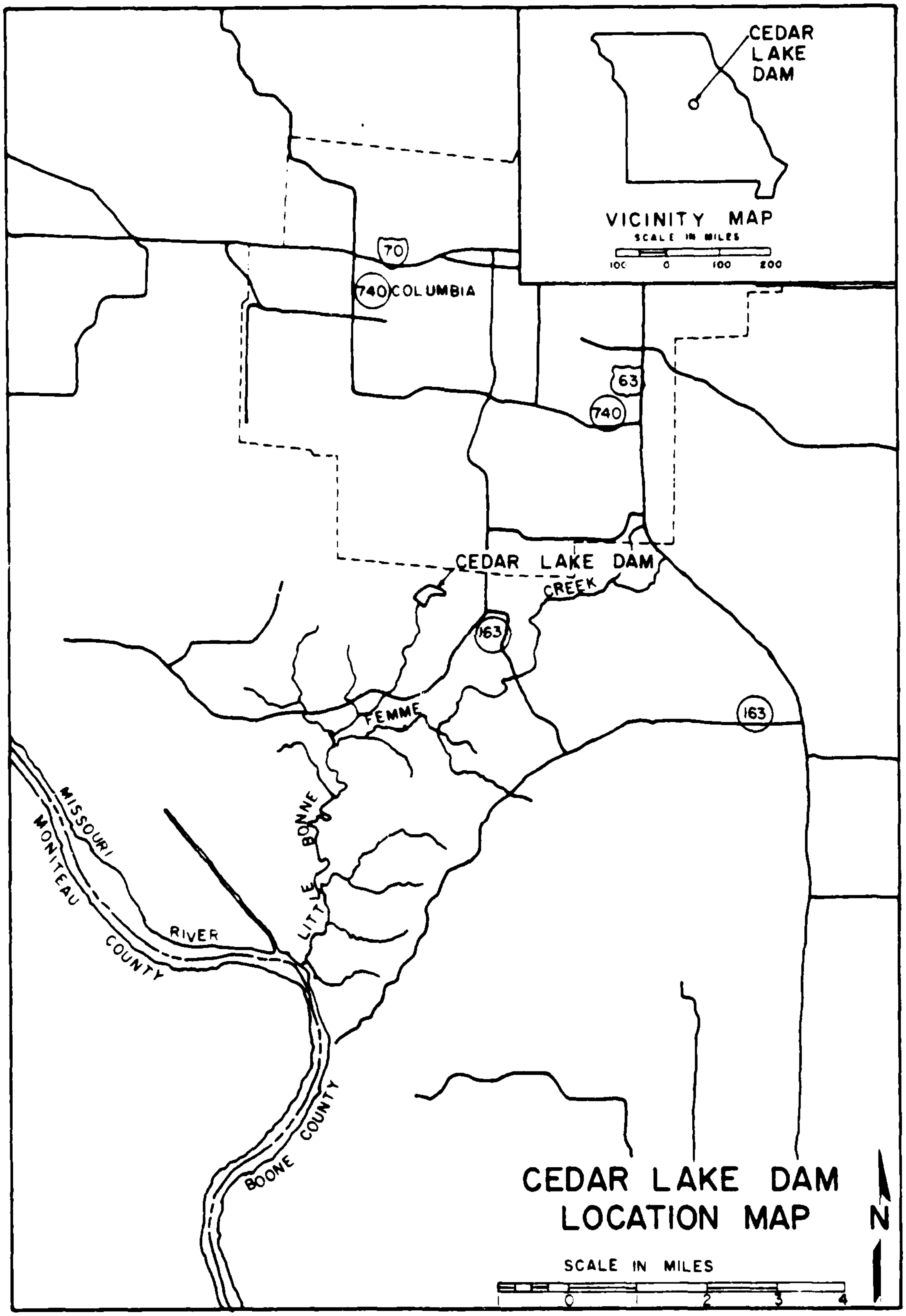
(4) An improved maintenance program to remove and control the growth of brush and trees in the spillway approach channel should be developed. Grass cover on the embankments should be planted, fertilized and maintained.

(5) The buildup of sediments in the spillway approach channel and in four of the spillway corrugated metal pipe-arches should be removed.

(6) The animal burrows in the embankment should be repaired since they can lead to piping. Control measures should be implemented to discourage increased animal activity in the area. The embankment slope should be monitored during this repair.

(7) Seepage and stability analysis should be performed.

(8) A detailed inspection of the dam should be made periodically. More frequent inspections may be required if additional deficiencies are observed or the severity of the reported deficiencies increase.



CEDAR LAKE DAM
VICINITY MAP
SCALE IN MILES
100 0 100 200
70
740 COLUMBIA
63
740
CEDAR LAKE DAM
CREEK
163
163
FEMME
LITTLE BONNE
MISSOURI RIVER
MONITEAU COUNTY
BOONE COUNTY
CEDAR LAKE DAM
LOCATION MAP
N
SCALE IN MILES
1 0 1 2 3 4

PLATE 1

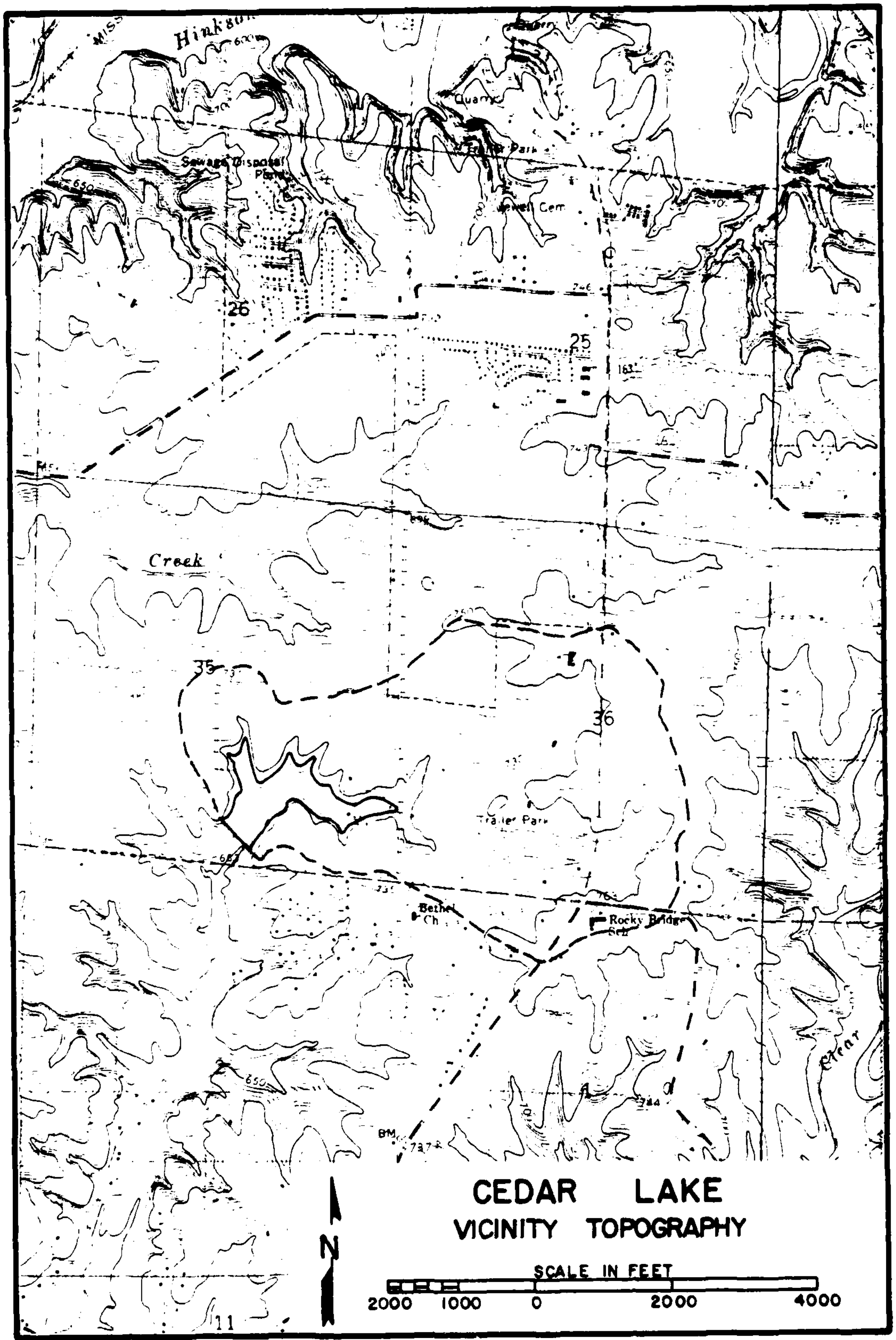

Hinkson
Sewage Disposal Plant
Quarry
Jewell Cem
Creek
Trailer Park
Bethel Ch
Rocky Bridge Sch
Clear
26
25
35
36
11
650
CEDAR LAKE
VICINITY TOPOGRAPHY
N
SCALE IN FEET
2000
1000
0
2000
4000

PLATE 2

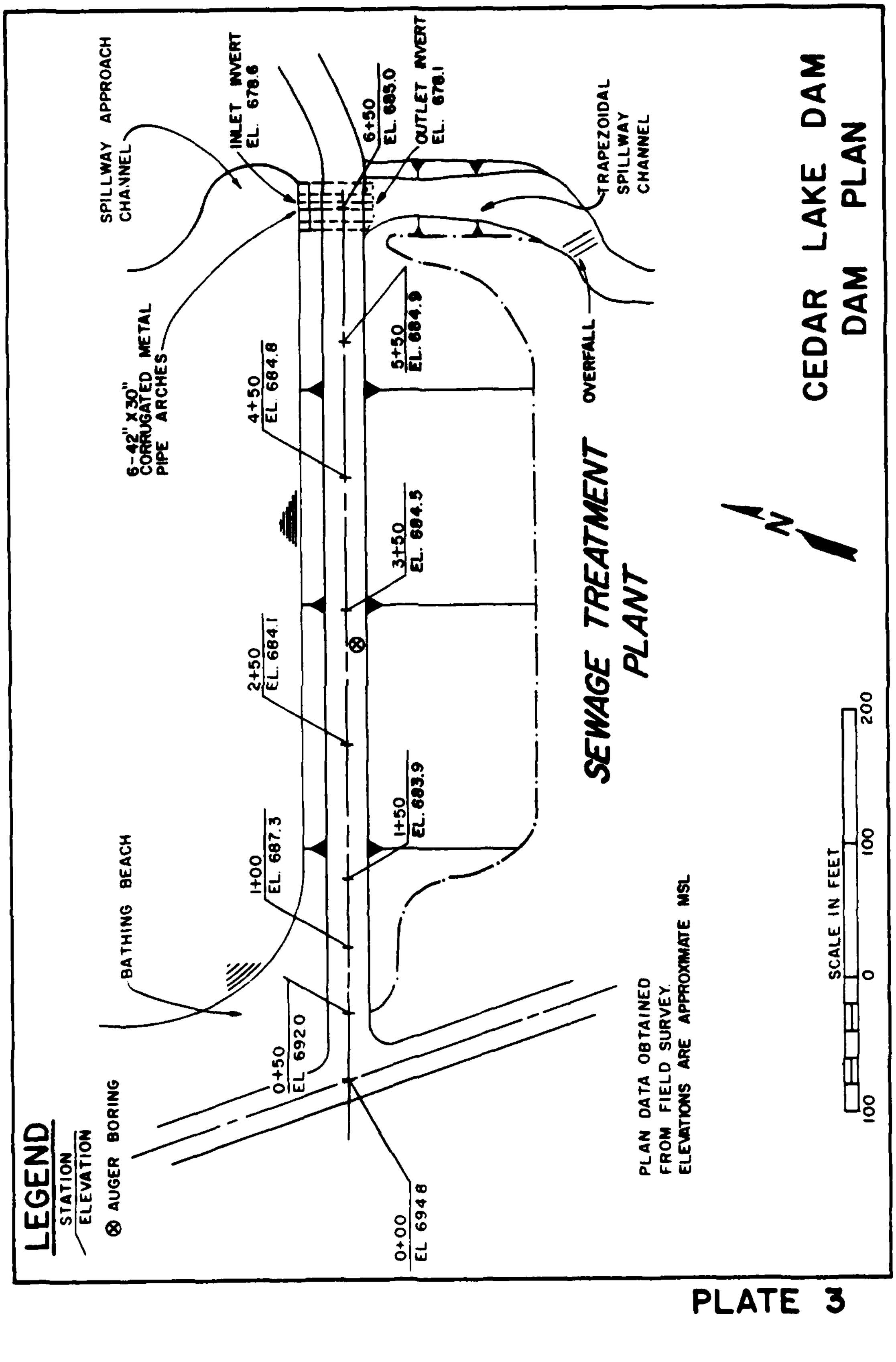

CEDAR LAKE DAM
DAM PLAN
LEGEND
STATION
ELEVATION
⊗ AUGER BORING
SPILLWAY APPROACH CHANNEL
INLET INVERT EL. 678.6
6+50 EL. 685.0
OUTLET INVERT EL. 678.1
TRAPEZOIDAL SPILLWAY CHANNEL
OVERFALL
6-42" X 30" CORRUGATED METAL PIPE ARCHES
4+50 EL. 684.8
5+50 EL. 684.9
3+50 EL. 684.5
2+50 EL. 684.1
1+50 EL. 683.9
1+00 EL. 687.3
0+50 EL. 692.0
0+00 EL. 694.8
BATHING BEACH
SEWAGE TREATMENT PLANT
N
PLAN DATA OBTAINED FROM FIELD SURVEY.
ELEVATIONS ARE APPROXIMATE MSL
SCALE IN FEET
100
0
100
200

PLATE 3

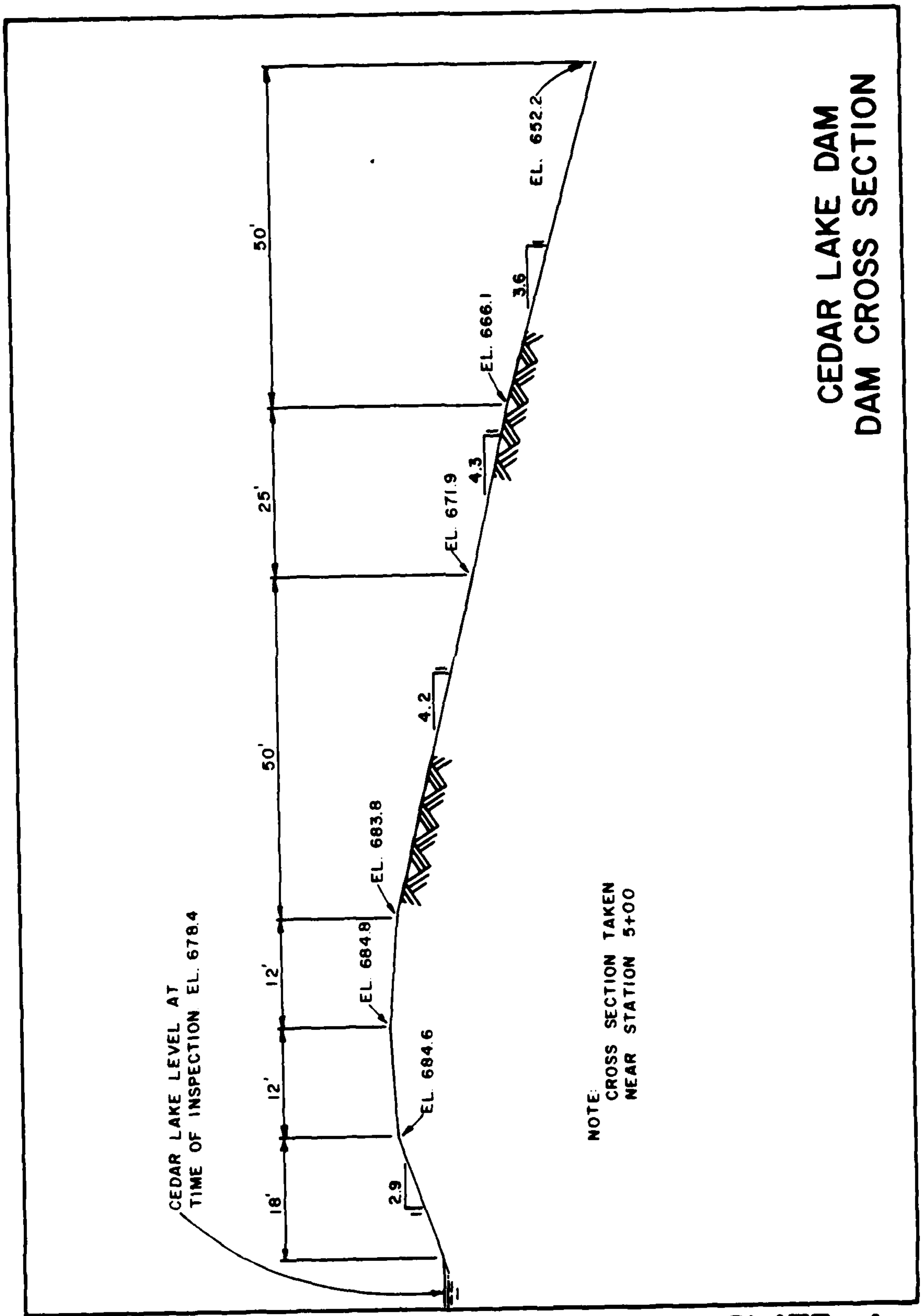

CEDAR LAKE DAM
DAM CROSS SECTION
CEDAR LAKE LEVEL AT
TIME OF INSPECTION EL. 678.4
18'
12'
12'
50'
25'
50'
2.9
1
EL. 684.6
EL. 684.8
EL. 683.8
4.2
1
EL. 671.9
4.3
1
EL. 666.1
3.6
1
EL. 652.2
NOTE:
CROSS SECTION TAKEN
NEAR STATION 5+00

PLATE 4

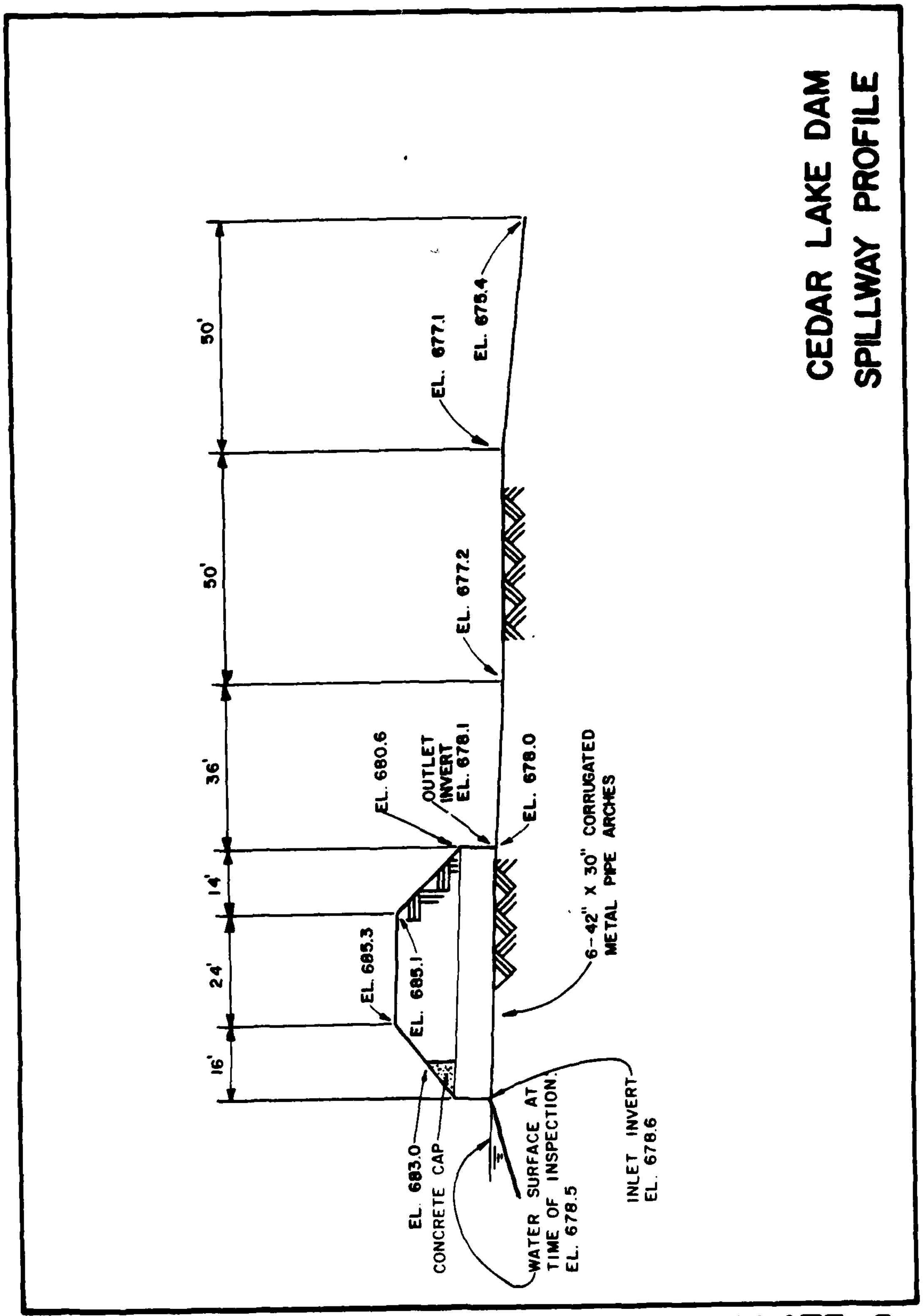
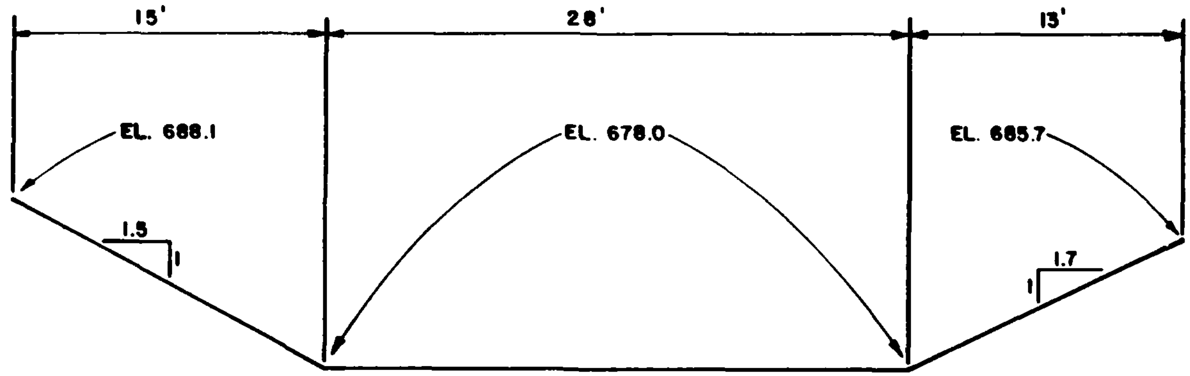
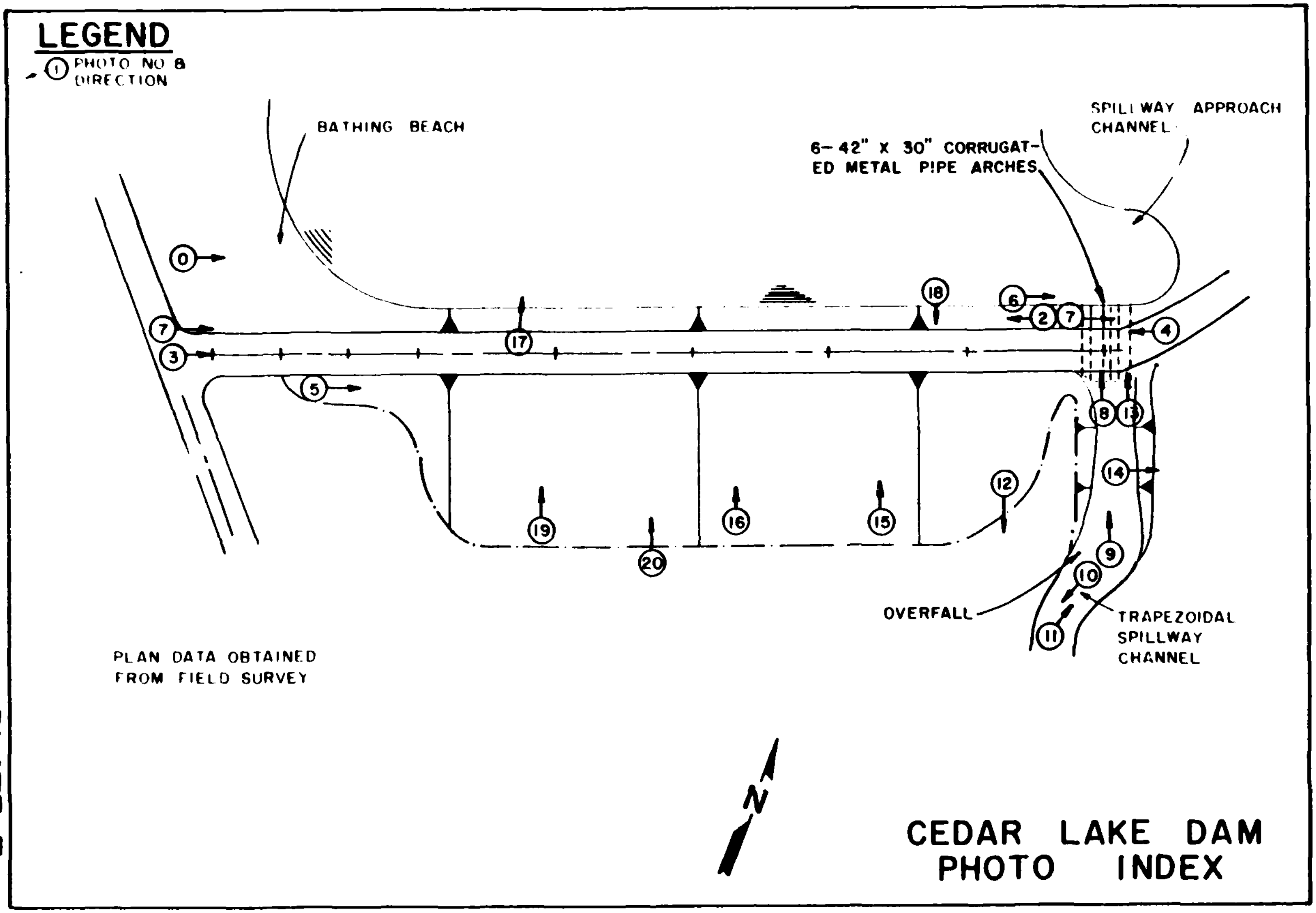

CEDAR LAKE DAM
SPILLWAY PROFILE
50'
50'
36'
14'
24'
16'
EL. 677.1
EL. 675.4
EL. 677.2
EL. 680.6
OUTLET INVERT EL. 678.1
EL. 678.0
6-42" X 30" CORRUGATED METAL PIPE ARCHES
EL. 685.3
EL. 685.1
EL. 683.0
CONCRETE CAP
WATER SURFACE AT TIME OF INSPECTION. EL. 678.5
INLET INVERT EL. 678.6

PLATE 5



NOTE:
CENTERLINE OF SPILLWAY
AT STATION 6+50

CEDAR LAKE DAM
SPILLWAY CROSS SECTION



LEGEND
1 PHOTO NO & DIRECTION
BATHING BEACH
6-42" X 30" CORRUGATED METAL PIPE ARCHES
SPILLWAY APPROACH CHANNEL
0
7
3
5
17
18
6
2
7
4
8
13
14
12
19
20
16
15
9
10
11
OVERFALL
TRAPEZOIDAL SPILLWAY CHANNEL
PLAN DATA OBTAINED FROM FIELD SURVEY
N
CEDAR LAKE DAM
PHOTO INDEX

PLATE 7

PHOTO 1: UPSTREAM FACE OF DAM LOOKING EAST

PHOTO 2: UPSTREAM FACE OF DAM LOOKING WEST

PHOTO 3: CREST OF DAM LOOKING EAST

PHOTO 4: CREST OF DAM LOOKING WEST

PHOTO 5: DOWNSTREAM SLOPE OF DAM

PHOTO 6: SPILLWAY APPROACH

PHOTO 7: UPSTREAM END OF SPILLWAY PIPES

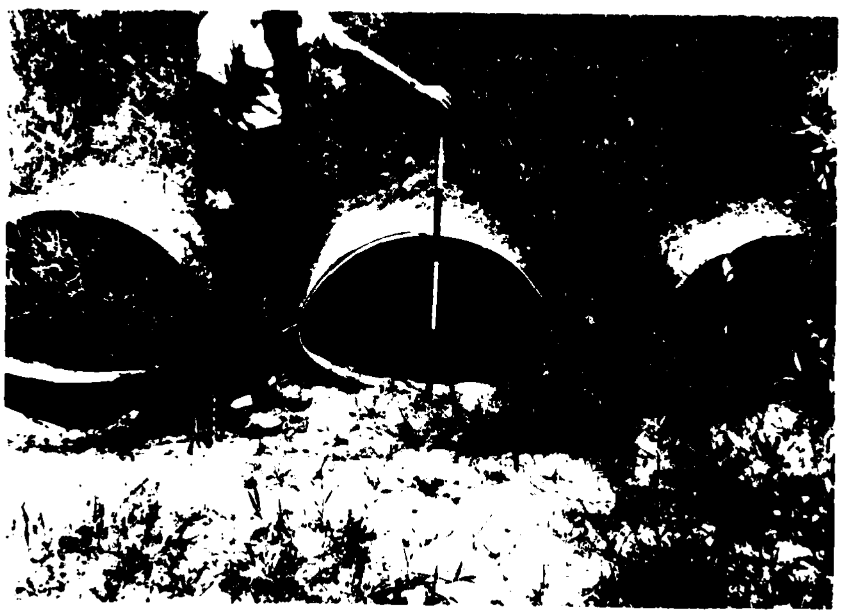


PHOTO 8: OUTLET END OF SPILLWAY PIPES

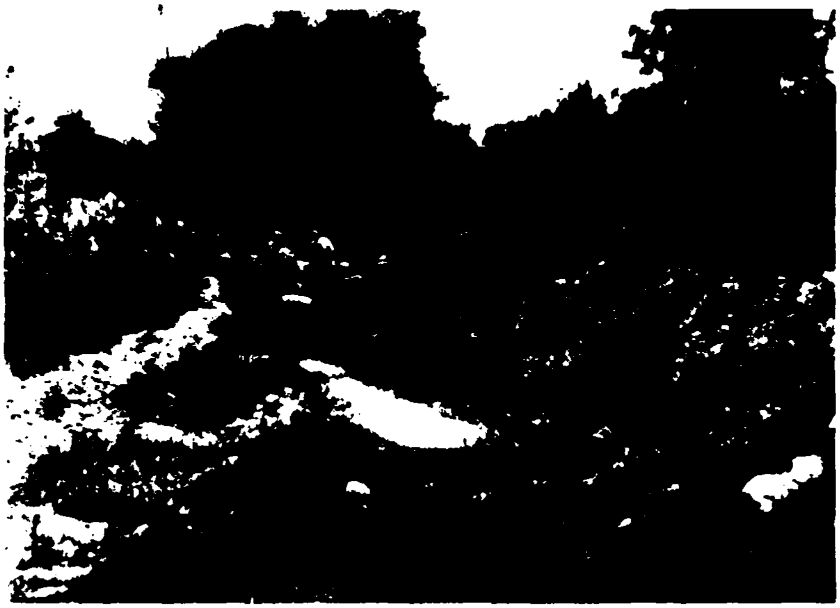


PHOTO 9: SPILLWAY CHANNEL LOOKING UPSTREAM

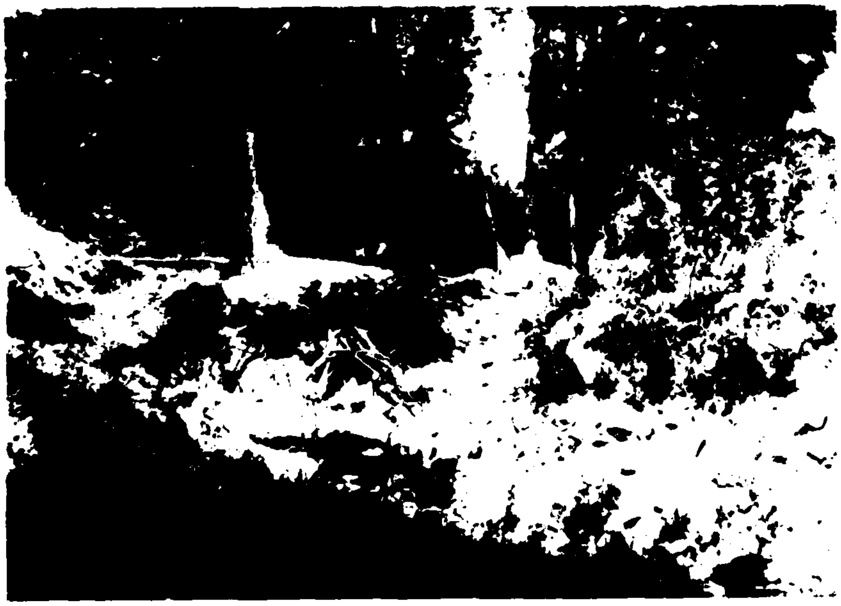


PHOTO 10: SPILLWAY OVERFALL LOOKING DOWNSTREAM

PHOTO 11: SPILLWAY OVERFALL LOOKING UPSTREAM

PHOTO 12: CHANNEL BELOW SPILLWAY OVERFALL VIEWED FROM TOP OF DAM

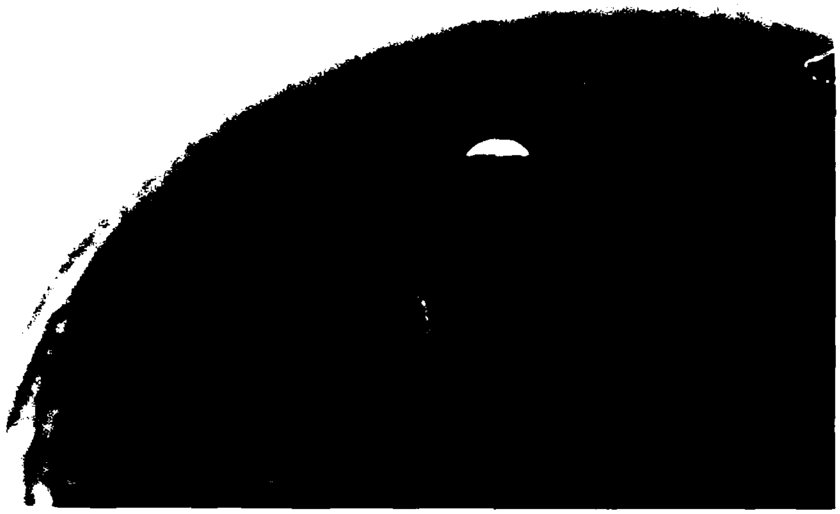


PHOTO 13: INSIDE SPILLWAY PIPE ARCH VIEWED FROM DOWNSTREAM END

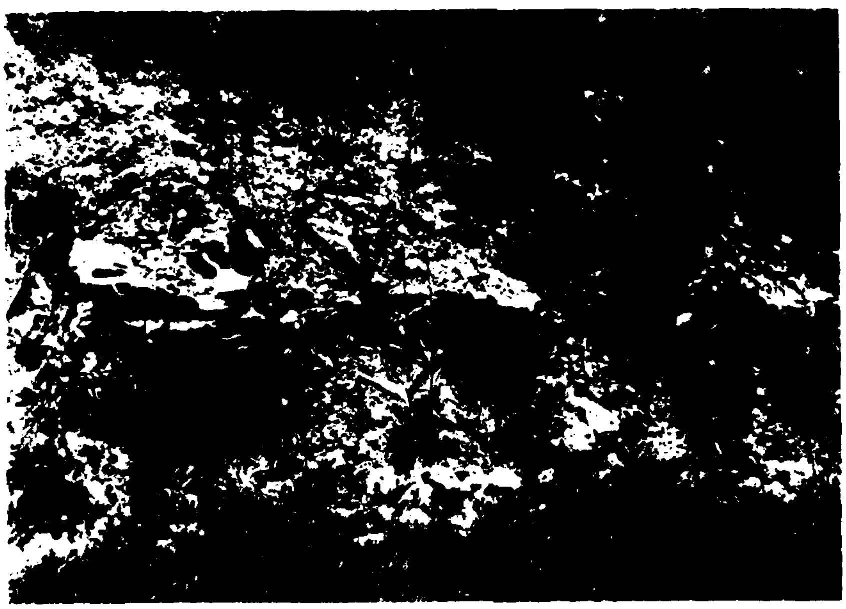


PHOTO 14: LEFT BANK CUT OF SPILLWAY CHANNEL

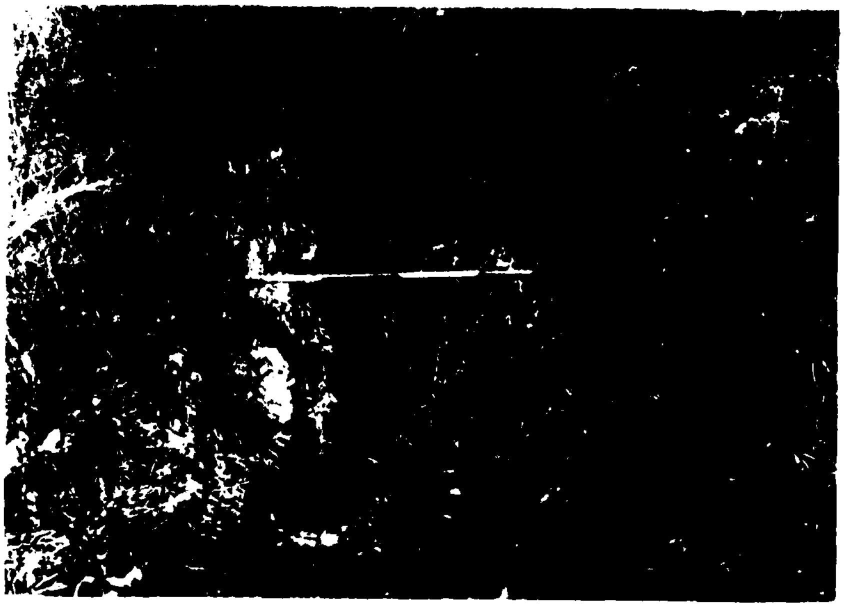


PHOTO 15: EROSION ON DOWNSTREAM SLOPE

PHOTO 16: EROSION ON DOWNSTREAM SLOPE

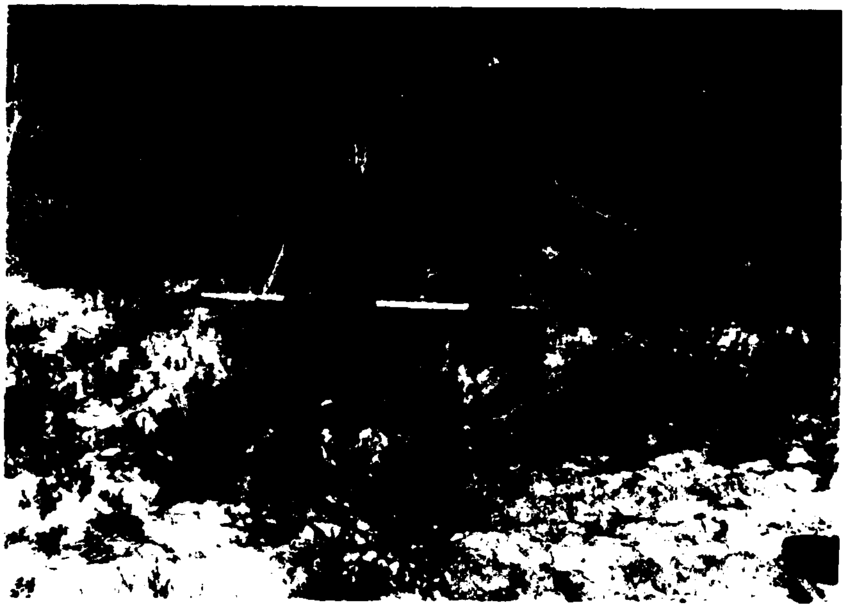


PHOTO 17: EROSION ON UPSTREAM SLOPE AT CREST

PHOTO 18: EROSION ON UPSTREAM SLOPE


PHOTO 19: ANIMAL BURROW ON DOWNSTREAM SLOPE


PHOTO 20: ANIMAL BURROW ON DOWNSTREAM SLOPE NEAR WEST END

APPENDIX A

HYDROLOGIC AND HYDRAULIC ANALYSES

HYDROLOGIC AND HYDRAULIC ANALYSES

To determine the overtopping potential, flood routings were performed by applying the Probable Maximum Precipitation (PMP) to a synthetic unit hydrograph to develop the inflow hydrograph. The inflow hydrograph was then routed through the reservoir and spillway. The overtopping analysis was determined using the computer program HEC-1 (Dam Safety Version) (1).

The PMP was determined from regional charts prepared by the National Weather Service in "Hydrometeorological Report No. 33" (HMR-33). Reduction factors were not applied. The rainfall distribution for the 48-hour PMP storm was determined according to the procedures outlined in HMR-33 and EM 1110-2-1411. The Jefferson City, Missouri rainfall distribution (15 min. interval - 48 hours duration), as provided by the St. Louis District, Corp of Engineers, was used when the one percent and ten percent chance probability floods were routed through the reservoir and spillway.

The synthetic unit hydrograph for the watershed was developed by the computer program using the Soil Converation Service (SCS) method. The parameters for the unit hydrograph are shown in Table 1.

The SCS curve number (CN) method was used in computing the infiltration losses for the rainfall-runoff relationship. The CN values used, and the result from the computer output, are shown in Table 2.

The reservoir routing was performed using the Modified Puls Method. The initial reservoir pool elevation for the routing of each storm was determined to be equivalent to the spillway pipe invert elevation of 678.6 feet m.s.l. in accordance with antecedent storm conditions preceding the one percent probability, ten percent probability, and probable maximum storms outlined by the U.S. Army Corps of Engineers, St. Louis District (2). The hydraulic capacity of the spillway and the storage capacity of the reservoir were defined by the elevation, surface area, storage, and discharge relationships shown in Table 3.

The rating curve for the spillway is shown in Table 4. The flow over the crest of the dam was determined using the non-level dam crest option ($L and $V cards) of the HEC-1 program. The program assumes critical flow over a broad-crested weir. The flow through the spillway was determined from nomographs for pipe-arch culverts with inlet or outlet control.

The result of the routing analyses indicates that 15 percent of the PMF will not overtop the dam.

A summary of the routing analysis for different ratios of the PMF is shown in Table 5.

The computer input data and a summary of the output data are presented at the back of this appendix.

TABLE 1

SYNTHETIC UNIT HYDROGRAPH

Parameters:

Drainage Area (A)	541 acres	
Hydraulic Length of Watercourse ( )	6,400 feet	
Hydrologic Soil Cover Complex Number (CN')	92 (AMC III)	81 (AMC II)
Average Watershed Land Slope (Y)	1.45%	
Lag Time (L_g)	0.75 hours (AMC III)	1.13 hours (AMC II)
Time of concentration (T_c)	1.25 hours (AMC III)	1.88 hours (AMC II)
Duration (D)	10 min. (AMC III)	15 min. (AMC II)

Time (Min.) *	Discharge (cfs) * AMC II	Time (Min.) *	Discharge (cfs) * AMC III
0	0	0	0
15	31	10	49
30	95	20	152
45	201	30	324
60	289	40	457
75	318	50	491
90	302	60	457
105	258	70	383
120	194	80	275
135	134	90	191
150	97	100	137
165	72	110	102
180	53	120	72

* From HEC-1 computer output

TABLE 1
(Continued)

FORMULAS USED:

$$L_g = \frac{0.8_{x}\ (S + 1)^{0.7}}{1{,}900 \times Y^{0.5}} \qquad (3)$$

$$S = \frac{1000}{CN' - 10}$$

$$T_c = L_g/0.6$$

$$D = 0.133\ T_c$$

TABLE 2

RAINFALL-RUNOFF VALUES

Selected Storm Event	Storm Duration (Hours)	Rainfall (Inches)	Runoff (Inches)	Loss (Inches)
PMP	48	34.79	33.77	1.02
1% Probability	48	8.71	6.41	2.30
10% Probability	48	5.89	3.78	2.11

Additional Data:

1) The soil associations in this watershed are Pershing, Weldon, Sharon, and Union (4).
   100 percent of drainage area in hydrologic soil group B.
   30 percent of the land use was urban.
   60 percent of the land use was cropland.
   10 percent of the land use was timberland (3 and 5).
2) SCS Runoff Curve CN = 92 (AMC III) for the PMF.
3) SCS Runoff Curve CN = 81 (AMC II) for the one percent and ten percent probability floods.

TABLE 3

ELEVATION, SURFACE AREA, STORAGE, AND DISCHARGE RELATIONSHIPS

Elevation (feet-MSL)	Lake Surface Area (acres)	Lake Storage (acre-ft)	Spillway Discharge (cfs)
*678.6	16.0	141	0
**683.9	22.8	241	301

*Spillway pipe invert elevation
**Top of dam elevation

The relationships in Table 3 were developed from the Columbia, Missouri. 7.5 minute quadrangle map and the field measurements.

TABLE 4

SPILLWAY RATING CURVE

Reservoir Elevation (ft-msl)	Spillway Discharge (cfs)
*678.6	0
680.0	67
681.0	104
682.0	195
683.0	258
683.9	301

*Spillway Crest Elevation
**Top of Dam Elevation

METHOD USED:

Spillway release rates were determined from nomographs for pipe-arch culverts with inlet or outlet control (6).

TABLE 5

RESULTS OF FLOOD ROUTINGS

Ratio of PMF	Peak Inflow (CFS)	Peak Lake Elevation (ft.-MSL)	Total Storage (AC.-FT.)	Peak Outflow (CFS)	Depth (ft.) Over Top of Dam
-	0	*678.6	141	0	-
0.15	713	683.8	238	294	0
0.50	2,377	685.7	282	2,317	1.8
1.00	4,755	686.4	302	4,651	2.5

* Spillway pipe invert elevation

BIBLIOGRAPHY

(1) U.S. Army Corps of Engineers, Hydrologic Engineering Center, Flood Hydrograph Package (HEC-1), Dam Safety Version, July 1978, Davis, California.

(2) U.S. Army Corps of Engineers, St. Louis District, Hydrologic/Hydraulic Standards, Phase I Safety Inspection of Non-Federal Dams, 12 December 1979.

(3) U.S. Department of Agriculture, Soil Conservation Service, National Engineering Handbook, Section 4, Hydrology, August 1972.

(4) U.S. Department of Agriculture, Soil Conservation Service, Soil Survey for Boone County, Missouri.

(5) U.S. Department of Agriculture, Soil Conservation Service, Technical Release No. 55, Urban Hydrology for Small Watersheds, January, 1975.

(6) U.S. Department of Commerce, Bureau of Public Roads, Hydraulic Engineering Circular No. 5, Hydraulic Charts for the Selection of Highway Culverts, December, 1965.

(7) U.S. Department of Agriculture, Soil Conservation Service, Soil Survey Interpretations and Field Maps, 1980.

(8) Mary H. McCracken, Missouri Division of Geological Survey, Geologic Map of Missouri, 1961.

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FLOOD HYDROGRAPH PACKAGE (HEC-1)
DAM SAFETY VERSION      JULY 1978
  LAST MODIFICATION  06 FEB 80
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   1        A1MISSOURI DAM INSPECTION PROGRAM
   2        A2ST. LOUIS DISTRICT US ARMY CORPS OF ENGINEERS
   3        A3CEDAR LAKE DAM - PMF
   4        B    288     0      10      0       0       0       0       0       0       0
   5        B1     5
   6        J      1      5      1
   7        J1    .1    .15     .2     .5     1.0
   8        K      0      1                             3       1
   9        K1   CEDAR LAKE (48 HR. PROBABLE MAXIMUM RUNOFF)
  10        M      1      2   .846                      1
  11        P          24.85   101    120     130     140
  12        T                                                  -1     -92
  13        W2           .75
  14        X                    1
  15        K      1      2                                     1
  16        K1   ROUTE THROUGH SPILLWAY
  17        Y                                   1       1
  18        Y1     1                                        -678.6     -1
  19        Y4 678.6  679.5  680.0  681.0  681.5  682.0  682.5  683.0  684.0  685.0
  20        Y4 686.0  687.0  688.0  689.0
  21        Y5    0.   32.4   67.2  104.4  156.0  195.0  228.0  258.0  306.0  348.0
  22        Y5 375.0  405.0  444.0  466.0
  23        SA0.0   16.0   17.2   31.6   54.2
  24        SE652.2 678.6  680.0  690.0  700.0
  25        SS675.6
  26        SD683.9
  27        SL0.    102.   210.   312.   418.   519.   582.   648.   701.   793.
  28        SV683.9 684.1  684.5  684.8  684.9  665.0  687.3  689.8  692.0  694.8
  29        K     99
```


PREVIEW OF SEQUENCE OF STREAM NETWORK CALCULATIONS

```
B L   . K   &   V E A T C H                                              PROJECT 9166.      DATE 31 [illegible]0   PAGE    4
****************************************************************************************************************************
FLOOD HYDROGRAPH PACKAGE - HEC-1                                         PROGRAM H21/02-0U  TIME  16:06:57   CASE PMF

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FLOOD HYDROGRAPH PACKAGE (HEC-1)
DAM SAFETY VERSION       JULY 1978
  LAST MODIFICATION  06 FEB 83
************************************
                       MISSOURI DAM INSPECTION PROGRAM
                       ST. LOUIS DISTRICT US ARMY CORPS OF ENGINEERS
                       CEDAR LAKE DAM - PMF

                                               JOB SPECIFICATION
                   NQ       NHR      NMIN      IDAY      IHR      IMIN    METRC     IPLT     IPRT    NSTAN
                  268         0        10         0        0         0        0        0        0        0
                                               JOPER      NWT     LROPT    TRACE
                                                   5        0         0        0

                                            MULTI-PLAN ANALYSES TO BE PERFORMED
                                                  NPLAN= 1 NRTIO= 5 LRTIO= 1
                      RTIOS=     .10     .15     .20     .50    1.00


              **********          **********          **********          **********          **********

                                                SUB-AREA RUNOFF COMPUTATION

                   CEDAR LAKE (48 HR. PROBABLE MAXIMUM RUNOFF)

                                   ISTAQ    ICOMP    IECON    ITAPE     JPLT     JPRT    INAME  ISTAGE    IAUTO
                                       1        0        0        0        0        3        1        0        0

                                                      HYDROGRAPH DATA
                   IHYDG     IUHG    TAREA     SNAP    TRSDA    TRSPC    RATIO    ISNOW    ISAME    LOCAL
                       1        2      .85      .00      .85     1.00     .000        0        0        0

                                                       PRECIP DATA
                              SPFE      PMS       R6      R12      R24      R48      R72      R96
                               .00    24.85   101.00   120.00   130.00   140.00      .00      .00

                                                        LOSS DATA
              LROPT    STRKR    DLTKR    RTIOL    ERAIN    STRKS    RTIOK    STRTL    CNSTL    ALSMX    RTIMP
                  0      .00      .00     1.00      .00      .00     1.00    -1.00   -92.00      .00      .00

                  CURVE NO =  -92.00  WETNESS =   -1.00  EFFECT CN =   92.00

                                                   UNIT HYDROGRAPH DATA
                                              TC=    .00     LAG=    .75

                                                      RECESSION DATA
                                      STRTQ=      .00   QRCSN=      .00   RTIOR= 1.00

                 UNIT HYDROGRAPH 24 END OF PERIOD ORDINATES, TC=      .00 HOURS, LAG=    .75  VOL= 1.00
                49.       152.       324.       457.       491.       457.       383.       275.       191.       137.
               102.        72.        53.        38.        27.        20.        14.        10.         7.         5.
                 4.         3.         2.         1.




B L A C K   &   V E A T C H                                              PROJECT 9166.      DATE 31 JUL 80   PAGE    5
****************************************************************************************************************************
FLOOD HYDROGRAPH PACKAGE - HEC-1                                         PROGRAM H21/02-0U  TIME  16:06:57   CASE PMF

            0                                   END-OF-PERIOD FLOW
```

END-OF-PERIOD FLOW

O MO.DA	HR.MN	PERIOD	RAIN	EXCS	LOSS	COMP Q
1.01	.10	1	.00	.00	.00	0.
1.01	.20	2	.00	.00	.00	0.
1.01	.30	3	.00	.00	.00	0.
1.01	.40	4	.00	.00	.00	0.
1.01	.50	5	.00	.00	.00	0.
1.01	1.00	6	.00	.00	.00	0.
1.01	1.10	7	.00	.00	.00	0.
1.01	1.20	8	.00	.00	.00	0.
1.01	1.30	9	.00	.00	.00	0.
1.01	1.40	10	.00	.00	.00	0.
1.01	1.50	11	.00	.00	.00	0.
1.01	2.00	12	.00	.00	.00	0.
1.01	2.10	13	.00	.00	.00	0.
1.01	2.20	14	.00	.00	.00	0.
1.01	2.30	15	.00	.00	.00	0.
1.01	2.40	16	.00	.00	.00	0.
1.01	2.50	17	.00	.00	.00	0.
1.01	3.00	18	.00	.00	.00	0.
1.01	3.10	19	.00	.00	.00	0.
1.01	3.20	20	.00	.00	.00	0.
1.01	3.30	21	.00	.00	.00	0.
1.01	3.40	22	.00	.00	.00	0.
1.01	3.50	23	.00	.00	.00	0.
1.01	4.00	24	.00	.00	.00	0.
1.01	4.10	25	.00	.00	.00	0.
1.01	4.20	26	.00	.00	.00	0.
1.01	4.30	27	.00	.00	.00	0.
1.01	4.40	28	.00	.00	.00	0.
1.01	4.50	29	.00	.00	.00	0.
1.01	5.00	30	.00	.00	.00	0.
1.01	5.10	31	.00	.00	.00	0.
1.01	5.20	32	.00	.00	.00	0.
1.01	5.30	33	.00	.00	.00	0.
1.01	5.40	34	.00	.00	.00	0.
1.01	5.50	35	.00	.00	.00	0.
1.01	6.00	36	.00	.00	.00	0.
1.01	6.10	37	.01	.00	.01	0.
1.01	6.20	38	.01	.00	.01	0.
1.01	6.30	39	.01	.00	.01	0.
1.01	6.40	40	.01	.00	.01	0.
1.01	6.50	41	.01	.00	.01	0.
1.01	7.00	42	.01	.00	.01	0.
1.01	7.10	43	.01	.00	.01	0.
1.01	7.20	44	.01	.00	.01	0.
1.01	7.30	45	.01	.00	.01	0.
1.01	7.40	46	.01	.00	.01	0.
1.01	7.50	47	.01	.00	.01	0.
1.01	8.00	48	.01	.00	.01	0.
1.01	8.10	49	.01	.00	.01	0.
1.01	8.20	50	.01	.00	.01	0.
1.01	8.30	51	.01	.00	.01	1.
1.01	8.40	52	.01	.00	.01	1.
1.01	8.50	53	.01	.00	.01	2.

MO.DA	HR.MN	PERIOD	RAIN	EXCS	LOSS	COMP Q
1.02	.10	145	.03	.03	.00	11.
1.02	.20	146	.03	.03	.00	14.
1.02	.30	147	.03	.03	.00	22.
1.02	.40	148	.03	.03	.00	32.
1.02	.50	149	.03	.03	.00	43.
1.02	1.00	150	.03	.03	.00	53.
1.02	1.10	151	.03	.03	.00	62.
1.02	1.20	152	.03	.03	.00	68.
1.02	1.30	153	.03	.03	.00	73.
1.02	1.40	154	.03	.03	.00	76.
1.02	1.50	155	.03	.03	.00	78.
1.02	2.00	156	.03	.03	.00	80.
1.02	2.10	157	.03	.03	.00	81.
1.02	2.20	158	.03	.03	.00	82.
1.02	2.30	159	.03	.03	.00	83.
1.02	2.40	160	.03	.03	.00	84.
1.02	2.50	161	.03	.03	.00	84.
1.02	3.00	162	.03	.03	.00	84.
1.02	3.10	163	.03	.03	.00	85.
1.02	3.20	164	.03	.03	.00	85.
1.02	3.30	165	.03	.03	.00	85.
1.02	3.40	166	.03	.03	.00	85.
1.02	3.50	167	.03	.03	.00	85.
1.02	4.00	168	.03	.03	.00	85.
1.02	4.10	169	.03	.03	.00	85.
1.02	4.20	170	.03	.03	.00	85.
1.02	4.30	171	.03	.03	.00	86.
1.02	4.40	172	.03	.03	.00	86.
1.02	4.50	173	.03	.03	.00	86.
1.02	5.00	174	.03	.03	.00	86.
1.02	5.10	175	.03	.03	.00	86.
1.02	5.20	176	.03	.03	.00	86.
1.02	5.30	177	.03	.03	.00	86.
1.02	5.40	178	.03	.03	.00	86.
1.02	5.50	179	.03	.03	.00	86.
1.02	6.00	180	.03	.03	.00	86.
1.02	6.10	181	.13	.13	.01	91.
1.02	6.20	182	.13	.13	.01	106.
1.02	6.30	183	.13	.13	.00	138.
1.02	6.40	184	.13	.13	.00	184.
1.02	6.50	185	.13	.13	.00	233.
1.02	7.00	186	.13	.13	.00	279.
1.02	7.10	187	.13	.13	.00	317.
1.02	7.20	188	.13	.13	.00	345.
1.02	7.30	189	.13	.13	.00	365.
1.02	7.40	190	.13	.13	.00	379.
1.02	7.50	191	.13	.13	.00	390.
1.02	8.00	192	.13	.13	.00	396.
1.02	8.10	193	.13	.13	.00	404.
1.02	8.20	194	.13	.13	.00	408.
1.02	8.30	195	.13	.13	.00	411.
1.02	8.40	196	.13	.13	.00	414.
1.02	8.50	197	.13	.13	.00	416.

1.01	9.00	54	.01	.00	.01	2.	1.02	9.00	198	.13	.13	.00	417.
1.01	9.10	55	.01	.00	.01	3.	1.02	9.10	199	.13	.13	.00	418.
1.01	9.20	56	.01	.00	.01	3.	1.02	9.20	200	.13	.13	.00	419.
1.01	9.30	57	.01	.00	.01	4.	1.02	9.30	201	.13	.13	.00	420.
1.01	9.40	58	.01	.00	.01	4.	1.02	9.40	202	.13	.13	.00	421.
1.01	9.50	59	.01	.00	.01	5.	1.02	9.50	203	.13	.13	.00	421.
1.01	10.00	60	.01	.00	.01	6.	1.02	10.00	204	.13	.13	.00	422.
1.01	10.10	61	.01	.00	.01	6.	1.02	10.10	205	.13	.13	.00	422.
1.01	10.20	62	.01	.00	.01	7.	1.02	10.20	206	.13	.13	.00	422.
1.01	10.30	63	.01	.00	.01	7.	1.02	10.30	207	.13	.13	.00	423.
1.01	10.40	64	.01	.00	.01	8.	1.02	10.40	208	.13	.13	.00	423.
1.01	10.50	65	.01	.00	.01	8.	1.02	10.50	209	.13	.13	.00	423.
1.01	11.00	66	.01	.00	.01	9.	1.02	11.00	210	.13	.13	.00	423.
1.01	11.10	67	.01	.00	.01	9.	1.02	11.10	211	.13	.13	.00	423.
1.01	11.20	68	.01	.00	.01	10.	1.02	11.20	212	.13	.13	.00	424.
1.01	11.30	69	.01	.00	.01	10.	1.02	11.30	213	.13	.13	.00	424.
1.01	11.40	70	.01	.00	.01	11.	1.02	11.40	214	.13	.13	.00	424.
1.01	11.50	71	.01	.00	.01	11.	1.02	11.50	215	.13	.13	.00	424.
1.01	12.00	72	.01	.00	.01	11.	1.02	12.00	216	.13	.13	.00	424.
1.01	12.10	73	.03	.01	.02	12.	1.02	12.10	217	.42	.41	.00	439.
1.01	12.20	74	.03	.01	.02	14.	1.02	12.20	218	.42	.41	.00	482.
1.01	12.30	75	.03	.02	.02	18.	1.02	12.30	219	.42	.42	.00	574.
1.01	12.40	76	.03	.02	.02	23.	1.02	12.40	220	.42	.42	.00	705.
1.01	12.50	77	.03	.02	.01	29.	1.02	12.50	221	.42	.42	.00	845.
1.01	13.00	78	.03	.02	.01	35.	1.02	13.00	222	.42	.42	.00	975.
1.01	13.10	79	.04	.02	.02	40.	1.02	13.10	223	.50	.50	.00	1069.
1.01	13.20	80	.04	.02	.02	46.	1.02	13.20	224	.50	.50	.00	1160.
1.01	13.30	81	.04	.02	.01	51.	1.02	13.30	225	.50	.50	.00	1262.
1.01	13.40	82	.04	.02	.01	56.	1.02	13.40	226	.50	.50	.00	1340.
1.01	13.50	83	.04	.03	.01	62.	1.02	13.50	227	.50	.50	.00	1410.
1.01	14.00	84	.04	.03	.01	66.	1.02	14.00	228	.50	.50	.00	1470.
1.01	14.10	85	.05	.03	.01	71.	1.02	14.10	229	.63	.63	.00	1523.
1.01	14.20	86	.05	.03	.01	76.	1.02	14.20	230	.63	.63	.00	1576.
1.01	14.30	87	.05	.04	.01	81.	1.02	14.30	231	.63	.63	.00	1641.
1.01	14.40	88	.05	.04	.01	85.	1.02	14.40	232	.63	.63	.00	1716.
1.01	14.50	89	.05	.04	.01	94.	1.02	14.50	233	.63	.63	.00	1790.
1.01	15.00	90	.05	.04	.01	100.	1.02	15.00	234	.63	.63	.00	1857.
1.01	15.10	91	.04	.03	.01	105.	1.02	15.10	235	.57	.57	.00	1909.
1.01	15.20	92	.07	.06	.01	110.	1.02	15.20	236	.95	.95	.00	1959.
1.01	15.30	93	.13	.11	.02	118.	1.02	15.30	237	1.72	1.71	.00	2064.
1.01	15.40	94	.33	.28	.05	143.	1.02	15.40	238	4.29	4.29	.01	2425.
1.01	15.50	95	.10	.08	.01	188.	1.02	15.50	239	1.24	1.24	.00	3075.
1.01	16.00	96	.06	.05	.01	247.	1.02	16.00	240	.76	.76	.00	3941.
1.01	16.10	97	.05	.04	.01	291.	1.02	16.10	241	.59	.59	.00	4561.
1.01	16.20	98	.05	.04	.00	306.	1.02	16.20	242	.59	.59	.00	4755.
1.01	16.30	99	.05	.04	.00	295.	1.02	16.30	243	.59	.59	.00	4548.
1.01	16.40	100	.05	.04	.00	269.	1.02	16.40	244	.59	.59	.00	4105.
1.01	16.50	101	.05	.04	.00	233.	1.02	16.50	245	.59	.59	.00	3535.
1.01	17.00	102	.05	.04	.00	204.	1.02	17.00	246	.59	.59	.00	3068.
1.01	17.10	103	.04	.03	.00	182.	1.02	17.10	247	.46	.46	.00	2736.
1.01	17.20	104	.04	.03	.00	168.	1.02	17.20	248	.46	.46	.00	2493.
1.01	17.30	105	.04	.03	.00	155.	1.02	17.30	249	.46	.46	.00	2282.
1.01	17.40	106	.04	.03	.00	144.	1.02	17.40	250	.46	.46	.00	2106.
1.01	17.50	107	.04	.03	.00	135.	1.02	17.50	251	.46	.46	.00	1957.
1.01	18.00	108	.04	.03	.00	127.	1.02	18.00	252	.46	.46	.00	1836.
1.01	18.10	109	.00	.00	.00	120.	1.02	18.10	253	.04	.04	.00	1723.

1.01	18.20	110	.00	.00	.00	111.	1.02	18.20	254	.04	.04	.00	1592.

B L   K & V E A T C H PROJECT 9166. DATE 11 [redacted]0 PAGE 7

FLOOD HYDROGRAPH PACKAGE - HEC-1 PROGRAM H21/C2-CU TIME 16:??:57 CASE PMF

1.01	18.20	110	.00	.00	.00	111.	1.02	18.20	254	.04	.04	.00	1592.
1.01	18.30	111	.00	.00	.00	98.	1.02	18.30	255	.04	.04	.00	1409.
1.01	18.40	112	.00	.00	.00	83.	1.02	18.40	256	.04	.04	.00	1154.
1.01	18.50	113	.00	.00	.00	67.	1.02	18.50	257	.04	.04	.00	954.
1.01	19.00	114	.00	.00	.00	52.	1.02	19.00	258	.04	.04	.00	745.
1.01	19.10	115	.00	.00	.00	40.	1.02	19.10	259	.04	.04	.00	572.
1.01	19.20	116	.00	.00	.00	31.	1.02	19.20	260	.04	.04	.00	445.
1.01	19.30	117	.00	.00	.00	25.	1.02	19.30	261	.04	.04	.00	357.
1.01	19.40	118	.00	.00	.00	21.	1.02	19.40	262	.04	.04	.00	292.
1.01	19.50	119	.00	.00	.00	17.	1.02	19.50	263	.04	.04	.00	247.
1.01	20.00	120	.00	.00	.00	15.	1.02	20.00	264	.04	.04	.00	216.
1.01	20.10	121	.00	.00	.00	14.	1.02	20.10	265	.04	.04	.00	193.
1.01	20.20	122	.00	.00	.00	12.	1.02	20.20	266	.04	.04	.00	175.
1.01	20.30	123	.00	.00	.00	12.	1.02	20.30	267	.04	.04	.00	164.
1.01	20.40	124	.00	.00	.00	11.	1.02	20.40	268	.04	.04	.00	156.
1.01	20.50	125	.00	.00	.00	11.	1.02	20.50	269	.04	.04	.00	150.
1.01	21.00	126	.00	.00	.00	10.	1.02	21.00	270	.04	.04	.00	145.
1.01	21.10	127	.00	.00	.00	10.	1.02	21.10	271	.04	.04	.00	142.
1.01	21.20	128	.00	.00	.00	10.	1.02	21.20	272	.04	.04	.00	140.
1.01	21.30	129	.00	.00	.00	10.	1.02	21.30	273	.04	.04	.00	138.
1.01	21.40	130	.00	.00	.00	10.	1.02	21.40	274	.04	.04	.00	137.
1.01	21.50	131	.00	.00	.00	10.	1.02	21.50	275	.04	.04	.00	135.
1.01	22.00	132	.00	.00	.00	10.	1.02	22.00	276	.04	.04	.00	136.
1.01	22.10	133	.00	.00	.00	10.	1.02	22.10	277	.04	.04	.00	136.
1.01	22.20	134	.00	.00	.00	10.	1.02	22.20	278	.04	.04	.00	136.
1.01	22.30	135	.00	.00	.00	10.	1.02	22.30	279	.04	.04	.00	136.
1.01	22.40	136	.00	.00	.00	10.	1.02	22.40	280	.04	.04	.00	136.
1.01	22.50	137	.00	.00	.00	10.	1.02	22.50	281	.04	.04	.00	136.
1.01	23.00	138	.00	.00	.00	10.	1.02	23.00	282	.04	.04	.00	136.
1.01	23.10	139	.00	.00	.00	10.	1.02	23.10	283	.04	.04	.00	136.
1.01	23.20	140	.00	.00	.00	10.	1.02	23.20	284	.04	.04	.00	136.
1.01	23.30	141	.00	.00	.00	10.	1.02	23.30	285	.04	.04	.00	136.
1.01	23.40	142	.00	.00	.00	10.	1.02	23.40	286	.04	.04	.00	136.
1.01	23.50	143	.00	.00	.00	10.	1.02	23.50	287	.04	.04	.00	136.
1.02	.00	144	.00	.00	.00	10.	1.03	.00	288	.04	.04	.00	136.

SUM 34.79 33.77 1.02 109828.
(884.)(858.)(26.)(3109.98)

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	4755.	2195.	724.	381.	109749.
CMS	135.	62.	21.	11.	3108.
INCHES		24.13	31.86	33.52	33.52
MM		612.97	809.23	851.44	851.44
AC-FT		1088.	1437.	1512.	1512.
THOUS CU M		1342.	1772.	1865.	1865.

HYDROGRAPH AT STA 1 FOR PLAN 1, RTIO 1

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	475.	219.	72.	38.	10975.
CMS	13.	6.	2.	1.	311.
INCHES		2.41	3.19	3.35	3.35
MM		61.30	80.92	85.14	85.14

HYDROGRAPH ROUTING

ROUTE THROUGH SPILLWAY

ISTAQ	ICOMP	IECON	ITAPE	JPLT	JPRT	INAME	ISTAGE	IAUTO
2	1	0	0	0	0	1	0	0

ROUTING DATA

QLOSS	CLOSS	AVG	IRES	ISAME	IOPT	IPMP		LSTR
.0	.000	.00	1	1	0	0		0

NSTPS	NSTDL	LAG	AMSKK	X	TSK	STORA	ISPRAT
1	0	0	.000	.000	.000	-679.	-1

STAGE	678.60	679.50	680.00	681.00	681.50	682.00	682.50	683.00	684.00	685.00
	686.00	687.00	688.00	689.00						
FLOW	.00	32.40	67.20	104.40	156.00	195.00	228.00	258.00	306.00	348.00
	375.00	405.00	444.00	468.00						

SURFACE AREA=	0.	10.	17.	32.	54.
CAPACITY=	0.	141.	164.	404.	828.
ELEVATION=	652.	679.	680.	690.	700.

CREL	SPWID	COQW	EXPW	ELEVL	COQL	CAREA	EXPL
678.6	.0	.0	.0	.0	.0	.0	.0

DAM DATA

TOPEL	COQD	EXPD	DAMWID
683.9	.0	.0	0.

CREST LENGTH	0.	102.	210.	312.	418.	519.	582.	648.	701.	793.
AT OR BELOW ELEVATION	683.9	684.1	684.5	684.8	684.9	685.0	687.3	689.8	692.0	694.8

STATION 2, PLAN 1, RATIO 1

END-OF-PERIOD HYDROGRAPH ORDINATES

OUTFLOW

0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	1.	1.	1.	1.
1.	1.	1.	1.	2.	2.	2.	2.	2.	3.
3.	3.	3.	4.	4.	4.	5.	6.	7.	7.
8.	8.	9.	9.	9.	9.	9.	9.	10.	10.
10.	10.	10.	9.	9.	9.	9.	9.	9.	8.
8.	8.	8.	8.	7.	7.	7.	7.	7.	6.
6.	6.	6.	6.	6.	6.	5.	5.	5.	5.

PEAK FLOW AND STORAGE (END OF PERIOD) SUMMARY FOR MULTIPLE PLAN-RATIO ECONOMIC COMPUTATIONS
FLOWS IN CUBIC FEET PER SECOND (CUBIC METERS PER SECOND)
AREA IN SQUARE MILES (SQUARE KILOMETERS)

OPERATION	STATION	AREA	PLAN	RATIO 1 .10	RATIO 2 .15	RATIO 3 .20	RATIO 4 .50	RATIO 5 1.00
				RATIOS APPLIED TO FLOWS				
HYDROGRAPH AT	1	.85	1	475.	713.	951.	2377.	4755.
	(	2.19)	(	13.46)(	20.20)(	26.93)(	67.32)(	134.64)(
ROUTED TO	2	.85	1	210.	294.	569.	2317.	4651.
	(	2.19)	(	5.96)(	8.33)(	16.10)(	65.62)(	131.69)(

SUMMARY OF DAM SAFETY ANALYSIS

SUMMARY OF DAM SAFETY ANALYSIS

PLAN 1 ....

	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	678.60	678.60	683.90
STORAGE	141.	141.	241.
OUTFLOW	0.	0.	301.

RATIO OF PMF	MAXIMUM RESERVOIR W.S.ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
.10	682.23	.00	206.	210.	.00	41.67	.00
.15	683.75	.00	238.	294.	.00	41.83	.00
.20	684.65	.75	258.	569.	2.83	41.17	.00
.50	685.66	1.76	282.	2317.	6.00	40.50	.00
1.00	686.43	2.53	302.	4651.	9.33	40.50	.00

END
DATE
FILMED
11-81
DTIC